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ABSTRACT

The purpose of this document is to provide a framework for school districts to use in the development of K-12 science curricula. The framework focuses on those ideas, skills, and attitudes that have the greatest educational significance for enabling the achievement of scientific literacy by all students. The scope of the Arizona Science Essential Skills addresses four aspects of science education: (1) "Teaching Science: Its Importance"; (2) "Defining Science Essential Skills Goals"; (3) "Achieving Scientific Literacy: Student Outcomes and Examples of Indicators"; and (4) "Implementing the Science Essential Skills". In Part 1, four of the reasons for revitalizing science education are summaries: the importance of science as a way for knowing and meeting personal needs; the relationship of science and technology to our democracy; economic vitality; and the environment. In Part 2, scientific and technological literacy is defined in eight specific goals. Part 3 forms the working guidelines with which school districts can evaluate existing curricula and develop new programs to meet the needs of students. Part 4 contains suggestions for implementing the science essential skills and identifies fundamental qualities of effective science curriculum and instruction. (KR)

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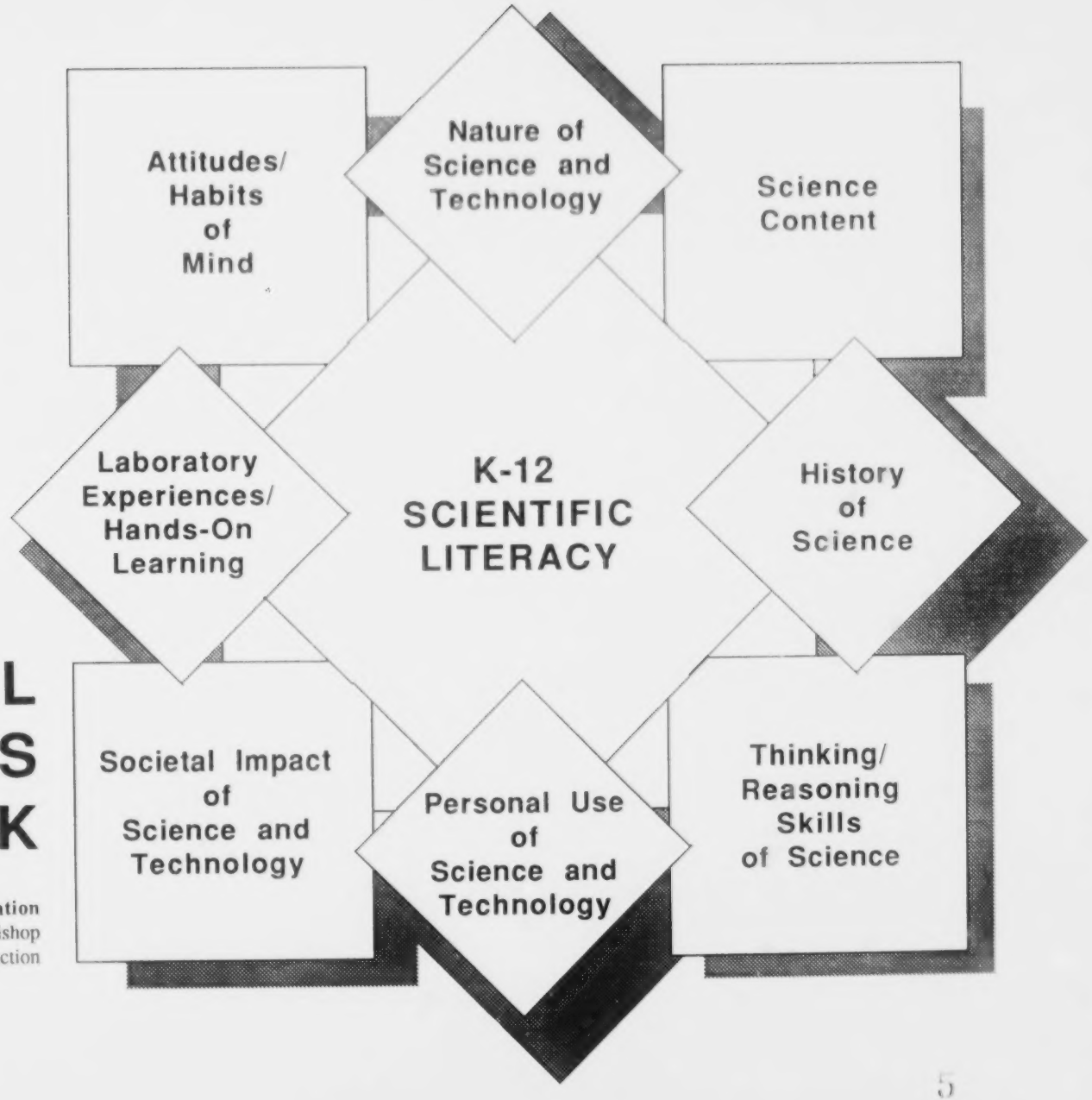
ARIZONA SCIENCE ESSENTIAL SKILLS

SE051699

ARIZONA DEPARTMENT OF EDUCATION
C. Diane Bishop, Superintendent
July 1990

ARIZONA SCIENCE ESSENTIAL SKILLS FRAMEWORK

Arizona Department of Education
C. Diane Bishop
Superintendent of Public Instruction


Attitudes/ Habits of Mind
Nature of Science and Technology
Science Content
Laboratory Experiences/ Hands-On Learning
K-12 SCIENTIFIC LITERACY
History of Science
Societal Impact of Science and Technology
Personal Use of Science and Technology
Thinking/ Reasoning Skills of Science

ARIZONA DEPARTMENT OF EDUCATION

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WHAT ARIZONA LAW REQUIRES

The Arizona Science Essential Skills Committee appointed by the State Board of Education was directed by law to develop a framework for science curriculum to be used by school districts. This document is called the Arizona Science Essential Skills.

Senate Bill 1327, Goals For Arizona's Educational Excellence, specifies the statewide student achievement goal for science education. Senate Bill 1327 states:

> "That appropriate efforts be made to help all of the students in this state master essential skills at the highest levels of thinking, to graduate from high school and to achieve their post-secondary goals. That by 1992, eighty percent, by 1996, 85 percent and by 2000, ninety percent of graduates in this state master core competencies as detailed in a list of essential skills adopted by the State Board of Education for each of the following student achievement goals. . .
>
> IN SCIENCE THAT GRADUATES ACHIEVE THE SCIENCE SKILLS AND KNOWLEDGE OF SCIENTIFIC PRINCIPLES, REASONING, TECHNOLOGY, AND HISTORY."

This goal statement was the beginning point from which the science essential skills committee developed the Arizona Science Essential Skills. The **Student Outcomes** listed in the Arizona Science Essential Skills are the core competencies that will be assessed in each school district through the Arizona Student Assessment Plan (ASAP).

The **Student Outcomes** in the Arizona Science Essential Skills will be used to establish the criteria by which instructional materials will be reviewed by the State Textbook Evaluation Committee.

Arizona Administrative Code

R7-2-301 states that science is to be taught in grades 1-8.

R7-2-302.02. establishes two credits of science as part of the 20 credits as the minimum number of credits necessary for high school graduation, effective for the graduation class of 1991.

PREFACE

Purpose

The purpose of this document is to provide a framework for school districts to use in the development of K-12 science curricula. The Arizona Science Essential Skills will assist science educators in creating a new K-12 continuum focusing on those ideas, skills, and attitudes having the greatest educational significance for enabling the achievement of scientific literacy by all students.

Development of Document

To create a document to meet this objective, The Science Essential Skills Committee:

1. conducted an extensive review of national and state documents and research;
2. selected from these documents those ideas having the greatest impact for science education for the next decade;
3. shared diverse perspectives representing educational, public and business interests;
4 received feedback on drafts from science educators and district curriculum specialists;
5. held public hearings; and
6. revised the draft after feedback from local school districts and the public.

Scope of Essential Skills Document

From the review of existing literature, it was obvious that there is an urgent need to improve science education in our country and state. The scope of the Arizona Science Essential Skills addresses four aspects of science education.

I. Teaching Science: Its importance
II. Defining Science Essential Skills Goals
III. Achieving Scientific Literacy: Student Outcomes and Examples of Indicators
IV. Implementing The Science Essential Skills

In Part I, Teaching Science: Its Importance, four of the most compelling reasons for revitalizing our science education programs in Arizona are summarized. The importance of science as a way of knowing and meeting personal needs, the relationship of science and technology to our democracy, economic vitality, and environment is reviewed.

In Part II, scientific and technological literacy is defined for Arizona students in eight specific goals. These goals call for the teaching of higher order thinking skills and the use of conceptual themes to provide students with the skills and the framework needed for lifelong learning. From the review of the literature it is evident that science education must change direction in order to adequately prepare students for the future. What is called for is a shift to an organization and presentation of science as fundamental concepts rather than as isolated facts. The need for this shift is based on the exponential growth of scientific knowledge. This proliferation of information prevents effective learning when science education is organized around teaching facts.

In Part III, these goals are detailed in the *Student Outcomes* and *Examples of Indicators* for Primary (K-3), Middle Grades (4-8), and Secondary (9-12). Part III forms the working guidelines with which school districts can evaluate existing curricula and develop new programs to meet the needs of scientific and technological literacy for Arizona's students. The format of Part III allows individual districts, schools, and teachers considerable latitude in determining curriculum to meet these goals. The *Student Outcomes* are mandated core competencies that must be used to develop district science curriculum. The *Examples of Indicators* are meant only as examples to stimulate further thought about the *Student Outcomes*, and are *not* prescriptive.

Part IV contains suggestions for implementing the science essential skills. This part identifies fundamental qualities of effective science curriculum and instruction. The importance of hands-on science programs is emphasized. Section IV will assist districts in the design of local curricula, determining appropriate instructional strategies, and establishing the necessary support structures for teachers for implementation.

I. TEACHING SCIENCE: ITS IMPORTANCE

Science educators and all citizens in Arizona have the responsibility as never before to prepare students to deal with a world which has been dramatically affected by science and technology. Scientifically and technologically literate citizens are able to understand, appreciate and enjoy the world, to make choices for personal affairs, to contribute to our state and nation's political and economic well-being, and to effectively care for our planet and work to improve its condition.

Science for Personal Affairs

Perhaps the most powerful mandate for teaching science to all students is to retain and increase the sense of joy and appreciation each has for the world. All children begin their education with inherent curiosity and wonder. Science teaching should foster, encourage and build upon that wonder through personal discovery and investigation. How much more wonderful to contemplate a flower and be aware, not only of its intrinsic beauty, but also of the precise and complicated structures and chemistry that operate together to produce the whole, and to realize the ways in which it fits into the larger picture of life.

A person's ability to use scientific methods of reasoning and thinking provides valuable tools which can be used for a lifetime in many ways. The power of each student to discover, observe, and problem-solve builds confidence and self-esteem, much needed in these times. As a person matures, the very nature of scientific attitudes and habits of mind fosters questioning and open-mindedness and continuing receptivity to information and lifelong learning. Such a scientifically and technologically literate person will be better able to cope with the technological advances in our society, and make decisions on their feasibility, application and use in their personal lives.

Each person can use science skills and attitudes to facilitate decision-making in many aspects of life: to choose between products and services; and to change careers or not. Scientific habits of mind allow a person to make rational conclusions based on evidence rather than using less reliable methods.

Science in a Democracy

The vigor and health of a democracy is determined by the attitudes, abilities and contributions of the people that comprise and shape it. There is truth in the

saying, "The strength of a democracy lies in an informed citizenry." Scientific habits of mind enable each citizen to have better decision-making capabilities at all levels, something very important in a democracy, which allows personal choices in many aspects of life.

A democracy also needs a scientifically and technologically literate populace to help enact legislation that deals with these issues, and that necessarily impacts on all other aspects of life. Informed citizens are capable of intelligent voting and of informing their representatives of their concerns and opinions.

Science and Economic Vitality

Science and technology permeate every part of local and national economic systems, from the industries and businesses that comprise the system, the products and services that are developed and marketed, to the storage and dissemination of information. To become an effective part of such a system, each person can benefit from becoming scientifically and technologically literate.

This literacy is also necessary to continue to refine society. More scientists and technologists are needed to increase the pace and number of studies and investigations. Such a multiplicity of effort results in greater accumulation of scientific knowledge and development of new technologies, with subsequent increase in new products, greater markets, increased productivity, and more diverse economic and entrepreneurial opportunities. Each state must do its share in producing educated persons in order for the United States to be economically competitive in a global market.

The global awakening and democratization occurring in the 1990's places a renewed importance on the scientific and technologic competence of Americans. Now as never before, the ability to become exporters of scientific and technologic skills and knowledge will determine not only economic success for the exporting nation, but will also provide a means to intelligent development and/or revitalization of emerging nations. The future economic vitality of the United States may hinge on the few critical decades to come.

Locally, Arizona's economic health depends on using science information and skills to determine how best to use the distinctive environmental and climatic resources available in this state without negatively impacting them, and producing a scientific and technologically literate work force. Arizona has a critical need to also address a demographic transition common to other border states—the shift of current ethnic minorities to become population majorities of the future. Minorities are potentially important economic forces that should not be overlooked in science education. In tandem with this is the encouragement of women in the fields of science and technology.

Science and Stewardship of the Environment

The diminishment of natural environments and the worldwide effects of humankind's historical and present activities are matters of ongoing and immediate concern. Today, such powerful tools exist that great environmental changes can be effected with little effort or time expended.

Science education should bring to each student an understanding of and love for the earth, its life and its systems. Knowledge obtained through personal investigations can motivate an involved concern that leads to an enlightened and ardent caretaking attitude. Arizona in particular has a fantastic and unique span of natural communities within its boundaries, and furnishes an unexcelled outdoor laboratory for its students. There exist many opportunities in Arizona for positive action about environmental matters on a local level, where each individual may contribute meaningfully.

In order to make appropriate choices and take proper actions in caring for the environment, both locally and globally, citizens must possess sufficient scientific and technologic skills and knowledge. There should also be heightened production of scientists and technologists who work specifically on gathering information about earth's natural environments. This greater understanding of what is actually there and how to protect it, will enable technologists to develop tools and products with less risk to natural environments. The kind of world shared by Arizona's citizenry in the next century depends, in large part, on educational reforms in science and technology that are begun and implemented now.

II. DEFINING SCIENCE ESSENTIAL SKILLS GOALS

Goal 1: Attitudes/Habits of Mind

To develop positive attitudes and excitement toward learning science and technology and to build confidence in one's ability to do and understand science.

Students' attitudes toward science and technology will be a powerful factor in determining the success of new programs for improving literacy in science and technology in Arizona. Science education programs should enhance students' interest in these subjects and help them discover new applications for science and technology in their personal lives.

In developing positive student attitudes toward science, building their self-esteem through experiences with science and technology and teaching them sound scientific attitudes, teachers should also be strong models of these attitudes for the students to emulate during their growth in science and technology.

Students' Self-Esteem

Positive experiences in science will help build students' self-esteem and provide a sense of accomplishment through personal involvement with laboratory and other active learning situations. A student's self-confidence about his or her ability in science is evidenced by risk-taking that leads to new learning, a sense of identity as an investigator and problem-solver, a sense of affiliation with other science students, and a sense of purpose for doing science.

Scientific Attitudes/Habits of Mind

Students should develop a working understanding of the following common attitudes and habits of mind, which are vital to the process and development of science and technology (Bybee, 1989):

1. **Curiosity:** Children and scientists alike are by nature curious. Science education should foster this natural curiosity. It should also help students understand how to use science as a method to seek answers for some of their questions and evaluate the plausibility of the answers they derive.

2. **Openness to New Ideas:** New ideas are essential for the growth of science, technology, and human enterprise in general. Science education should promote the value of listening to and evaluating new ideas even if an idea is different from what the student currently believes.

3. **Skepticism**: Students should recognize that skepticism about theories and ideas is a normal part of the process of science. A new theory must stand the test of critical review before it becomes accepted as valid. Students should understand how to strike a proper balance between skepticism and openness to new ideas.

4. **Reliance on Data, Facts, and Observations:** Students should develop the habit of asking for and weighing supporting evidence before accepting a new idea or theory of their own or others.

5. **Respect for Reason:** The patterns of reasoning used to develop theories and to derive scientific conclusions are very important in determining the validity and acceptance of a theory. Science education should help students learn to follow patterns of reasoning used in scientific thought and in developing theories and technological solutions to problems.

6. **Honesty and Objectivity:** Data should be presented in an honest, straightforward manner. Experiments should be designed to reveal scientific truths, not just to support a particular point of view.

7. **Acceptance of Ambiguity:** Science and technology students must learn to recognize that real-world data and facts are seldom clear and compelling; and scientific information rarely proves a point, it provides evidence for a point of view. It is the ambiguous nature of scientific pursuits which provides inspiration for new research.

8. **Willingness to Modify Explanations:** Students should learn that scientific theories are not fixed. Scientists should and do strive to ever improve explanations for natural phenomena. Scientists must be willing to modify existing theories if new evidence warrants a change.

9. **Sense of Cooperation:** With increasing specialization of scientific fields, successful teamwork has become essential for many scientific investigations. Science education can greatly benefit students' personal lives (school achievement, working relationships, and community service) through cooperative learning experiences.

Goal 2: Nature of Science and Technology

> **To develop an understanding about the nature of science and technology.**

Science and technology are closely interrelated fields and figure prominently in today's world. Technology has achieved dazzling tools and products, and has pervaded our daily lifestyle to the extent that it somewhat overwhelms science in popular thought, and is frequently mistaken for it. It is important that students in Arizona's classrooms understand the differences, as well as the similarities, between science and technology, and that they become able to carry out activities in either field.

Recent definitions of science and technology by R. W. Bybee et al. (1989) concisely differentiate the two:

> "Science proposes explanations for that which is observable, whereas technology proposes solutions for problems of human adaptation to the environment."

There are many ramifications and interconnections between science and technology that are not simplistic. It is important to understand that the terms of "science" and "technology" refer primarily to the processes involved in creating scientific explanations and technological solutions and secondarily to the bodies of knowledge that have resulted in both fields.

What is Science?

Science has its roots in the inborn human curiosity about the natural world and the need to understand and make sense of it. With the advent of written language came the ability to record and pass, from generation to generation, the observations

and thoughts of many people. What developed were particular ways of observing, thinking, experimenting, and validating These resulted in the process for producing knowledge that we call science.

Science begins with the assumption that what exists and happens in nature is understandable, and that these things fit into a common universal set of patterns. Scientists investigate natural phenomena by using methods of scientific inquiry. These include gathering of evidence by observation and measurement; formulating hypotheses to be tested; applying reasoning to data gathered; and devising a rational explanation or theory that fits what has been observed. To be validated, the explanation should prove predictive. Separate observations not included in the original study should also fit the explanation.

Science involves observing, recording, and correlating. The scientist may need to be creative in planning and carrying out a study so that unbiased observations can be made. Although science strives to discover facts and truths, results and conclusions do not represent rigid dogma because they are always subject to change as a result of additional study. The parts of explanations that continue to fit are retained and built upon, so that an increasing body of knowledge is produced that more closely approximates what actually exists. Science essentially comes up with various estimates of parameters and never claims to come up with the parameters themselves.

What is Technology?

Human creativity and the ability to be manipulative are the main qualities that give rise to technology. People seek to use available information and resources to modify their surroundings and even themselves to become more efficient, comfortable, healthy, attractive, productive, better defended, and a host of other desired human conditions. At any one time in history, technology can be viewed as the currently most efficient mass of recipes, architecture, machinery, or procedures which we use in our lives, business, and industry. As with scientific knowledge, most features of technology become obsolete and are replaced.

Technology uses information resulting from science, but does not automatically come from science. Rather, it results from mankind's creativity in utilizing science to serve needs.

Reciprocity exists between technology and science. Although technology depends on science, science also depends on technology for devices and techniques that extend the range of observations and measurements that are possible. Technological advances may also stimulate fresh scientific inquiries in disciplines where appropriate instruments and tools were not previously available. Technology uses many of the same investigative techniques that science uses; however, the end products are different. They both share a common and important tool, mathematics.

Because technology modifies the natural world, rather than simply seeking to understand it as does science, there are risks and tradeoffs involved in technological development. The real possibility exists that a given technological system may fail or have unexpected consequences. Assessing possible effects and risk factors should be an inherent part of implementing technology.

Goal 3: Science Content

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Science knowledge accumulates gradually as scientists work to construct explanations of observable phenomena. This knowledge aids in understanding how the universe operates and helps people to evaluate their place, significance, and role in the total environment. Over the years, science knowledge has been divided into areas of investigation or disciplines, such as biological, physical, and earth sciences. Disciplinary divisions have been valuable to practicing scientists and for students engaged in studying a field in depth. The traditional practice in American schools has been to structure science curriculum around disciplinary division resulting in a "layer-cake curriculum." That is, students are exposed to one science discipline one year and then move on to another discipline the next. This practice can frequently restrict the learning of science because many concepts and problems involve two, three, or more science disciplines as well as other subject areas. In addition, science and technology are expanding so rapidly that trying to incorporate all this knowledge into elementary and secondary science curricula has become futile. The information explosion has led to encyclopedic textbooks and science curricula that consists of lists of terms and facts given to students to read and recite.

An alternative structure to use in organizing science and technology curricula consists of identifying major organizing concepts in science and then choosing the science knowledge components of the curriculum based on their utility in adding to the students' understanding of these concepts. These organizing concepts should repeatedly appear in the K-12 science curriculum using specific topics from all disciplines of science. This integrative approach allows students to develop a meaningful framework for understanding science and technology and the interrelationships among the science disciplines. (Bybee, 1989)

There are several reasons for using these organizing concepts as a framework for science and technology curriculum development. First, all disciplines of science are permeated by these concepts. For example, the concept of change or organization can be found in any subfield of science. Second, incorporating these concepts throughout the K-12 curriculum will result in students understanding logical and material interrelationships of all sciences. Third, the underlying principles illustrated by these concepts are integral in the "doing" of science and consequently, should become integral in the teaching of science. Fourth, they reinforce the importance of understanding the ideas in science, rather than the memorization of isolated facts. Finally, these concepts are so powerful as explanations for both experiences in the classroom as well as things encountered in a child's life that they provide a great deal of utility in connecting real life to educational experiences. (Bybee, 1989)

The eight organizing concepts selected by the committee represent fundamental explanatory principles that will have a lasting value to students. The concepts of **organization, cause and effect, systems, models, change, structure and function, diversity, and interactions** are central to a sound science curriculum. These concepts pervade all disciplines of science and appear repeatedly, whether we are looking at the human body, the solar system, or computers. Doubtless, other lists could be compiled that would serve the same purposes. It is the intent of this goal to provide a new structure for science curricula that is more relevant, lasting, and useful for all students. Brief descriptions of these concepts are provided to clarify the concept and illustrate the concept in a teaching context.

Organization. Ideas and descriptions about the world can be organized in many ways, including patterns, groups, hierarchies, relationships, and symmetry. For example, objects in nature can be assembled into groups showing a hierarchy—

atoms, molecules, mineral grains, rock strata, hills, mountains, and planets. In Arizona, the relationship between elevation and ecosystem is seen in the biomes of desert, chaparral, mountain, riparian, and grassland.

Cause and Effect. Searching for causes and explanations is one of the major activities of science. Following scientific processes and procedures can lead to the discovery of causes for many phenomena children encounter in their lives. For a plant to be healthy and grow, seeds need water, light and warmth; simple experiments can show the effect of varying each of these conditions. Some events require that many things need to happen to cause an effect. The formation of the Grand Canyon has many contributing causes. The misconception to avoid is that when events happen simultaneously or sequentially, a cause-and-effect relationship always exists. The position of a planet and a death in the family may occur simultaneously, but there is not a causal interrelationship.

Systems. Systems consist of matter, energy and information, broken down into subunits which are somewhat isolated from each other, but all interacting in complex ways. Many systems can be delineated and understood in science and technology. A common technological system is the furnace and thermostat. A common natural system is the hydrologic cycle in which water moves about the earth, sometimes residing in the atmosphere, sometimes in living tissue, and sometimes in streams, lakes, ground water or oceans.

Models. Models are useful to understand the essential character of some phenomena. Models can be conceptual and consist of word descriptions or drawings. Models can also be mathematical and consist of equations or other formal representations. Physical models that consist of real objects but are different from the actual thing in terms of scale or material can also be useful. The solar system is often modeled by describing the planets as balls moving about an even larger ball representing the sun. On another level, a model solar system might include mathematical models to include a scale indicating distances between planets or the shape of orbits being elliptical. A physical model of the solar system might consist of scale-sized balls placed at appropriate distances along a hallway.

Change. Change occurs on various time frames in the natural world. Some object or organisms seem unchanging, but that is a function of our inability to

perceive the rate or scale of the change. For example, mountains erode and species adapt, but the time required to recognize substantial change is quite long. Some change is cyclical; that is, the direction of the change is reversed. Day/night cycles, lunar cycles, and seasonal cycles are examples. For any particular event or phenomena, the rate of change of individuals or parts may vary. For example, all children grow to some adult height, but certainly not at the same rate.

Structure and Function. The way organisms and objects look, feel, smell, sound and taste has a relationship to the actions they perform. Many structures found on desert plants function to conserve water. This relationship of structure to function is very evident in many technologies. Specific tools are designed to perform specific tasks.

Diversity. There are many different types of objects, organisms, and systems in the world. Although we impose organizational structures to help us understand our world, students should not lose sight of the complexity and diversity of the real world. Not only are there many different types of objects and organisms, but also there is considerable variation within these types. For example, within the species *Homo sapiens*, even though all people share many common characteristics, there is great individual diversity in appearance, behavior, and genetics.

Interactions. Interactions between energy and matter determine the nature of the environment. There are many interactions among the components of systems. Carbon dioxide, solar energy, and water react in a chloroplast to produce sugars, oxygen, energy and heat in the photosynthetic system. A part of the interaction pattern of a system is feedback. If a deer population increases in an area one year, it may overgraze its habitat. This may increase the starvation rate the next year, thus reducing the population to its appropriate size for that habitat.

Goal 4: History of Science

> **To understand the historical contributions in science and the content in which they were made.**

This goal focuses on the progression of science and technology, major scientific achievements, and the social-historical context in which they were made. Appreciation of our scientific and technological society requires an understanding of the scientific milestones that have changed our way of life and of the economic, political, and social factors influencing these accomplishments. The

ability of students to be able to trace the progression of scientific and technological development enables them to grasp the complexity of our present world.

Historical milestones include the discoveries of Kepler, Galileo, Copernicus, and Newton, and the modern developments of the twentieth century that have led to a clearer understanding of the world and solutions to our problems. Placing these major scientific accomplishments in their social and historical settings provides examples of how various factors and personalities impacted these developments. Studying stories of the contributions of scientists or groups of scientists demonstrates how the scientific enterprise works and clarifies the role of scientific and technological developments to our cultural heritage.

The history of science encompasses an understanding of the social communities and historical settings in which scientists work and how this context affects the formulation and assimilation of new theories and discoveries. Scientific and technological research within Arizona is a source of examples. An understanding of the historical setting or social context in which scientific discoveries were made develops an appreciation of the evolution of science. (Far West Laboratory, 1989.)

Goal 5: Reasoning/Thinking Skills

To develop integrated thinking skills through science experiences.

The goal of the student outcomes in this section is to develop in students reasoning abilities that are not only essential tools for the professional scientist, but are also patterns of thought that serve people well in all walks of life. They are essential for an informed and effective democratic citizenry. The skills are grouped into rational, critical, and creative thinking categories. In most complex thinking processes students will integrate skills from all of these categories.

There is a continual dynamic interaction between the content of science or technology and thinking processes that characterize these enterprises. This goal is intended to ensure that students are given repeated opportunities through "hands-on," "minds on" experiences to learn and use inquiry methods and problem-solving strategies that will contribute to their understanding of science and technology. This will enhance their ability to reason logically, to solve problems rationally, and to think critically and creatively. These skills enhance

the ability to explore nature, to raise questions, to generate multiple tentative explanations for phenomena, and to test these explanations through the deduction of their logical consequences and through a comparison with evidence.

Rational thinking skills are useful when knowledge is utilized to identify, delineate, and solve scientific and technological problems. These include many of the science process skills. They aid students in sensing and researching problems, formulating and revising procedures, and generating and choosing alternative explanations. These skills are used extensively when students engage in problem-solving and decision-making while designing scientific investigations and examining science related societal issues.

Critical thinking skills allow students to reorganize knowledge and to apply it to new issues, situations and subjects. These skills are also employed by students during the process of conducting scientific investigations. They aid in comparing and inferring from data, identifying and recognizing assumptions or relationships, and assessing and verifying information. Overall critical thinking skills are used when students analyze and evaluate information and make connections among specific informational parts.

Creative thinking skills are necessary when students must generate new knowledge from past experiences. They help during hypothesizing and summarizing and also aid in expanding and extending investigations. In general these skills help students during elaborating, synthesizing, and imagining experiences. These skills are purposely incorporated in this goal area to develop a student's imagination in regards to the problems of increasingly complex social and political institutions, environmental and energy problems, and everyday life experiences.

Goal 6: Personal Use of Science and Technology

To use experiences with science and technology in personal decision-making.

This goal focuses on helping students to understand the science and technology that they encounter in their daily lives and to utilize their knowledge of science and technology in making personal decisions. Students encounter science concepts daily through their experiences with technology and the environment. An understanding of basic science concepts operating in technological devices and in the environment is critical to a scientific literate population.

Scientific understanding and reasoning abilities can help students make informed decisions about consumerism, their own health, and activities. This goal area considers those choices and issues students are likely to experience and confront as individuals that require a science background. In the daily lives of students in Arizona, personal choices are made that require an understanding of science and technology. The personal use of science and technology focuses on scientific understanding at the level of individual action. (Far West Laboratory, 1989)

A degree of scientific literacy is important for students to be able to make informed choices about careers. Students need to be aware of the role of science and technology in most careers. This requires interaction with professionals and workers from a variety of fields. The student outcomes in this goal help students develop an awareness of the nature, scope, and wide variety of science-technology-related careers open to individuals of varying aptitudes and interests.

Goal 7: Societal Impact of Science and Technology

To increase understanding of the limits, possibilities, and interrelationships among science, technology, society, and the environment.

It is recognized that people experience science in a social context, thus scientifically informed citizens must be aware of how science, technology, and society influence one another and impact the environment. The student outcomes for this area focus on developing understandings and acquiring knowledge which will help when crucial decisions about scientific issues must be made. The influence of science and technology on humans, societies and environments at local, state, national, and global levels is also emphasized.

Science and technology impact on society in many ways. Just as explanations about the world are imperfect and incomplete, technological solutions to problems are imperfect and incomplete. All technologies carry unexpected benefits, unexpected costs and unexpected risks which may vary for different social groups. The degree to which any society depends upon technology is also the degree to which the society must accept the burden of risk. Anticipating the effects of technology is as important as advancing its capabilities.

Societal decisions also influence the advancement and development of science and technology. Collective interactions and needs of human beings at local,

state, national, and global levels determine demands for technological solutions and products. Social and economic forces strongly influence which technologies we will consider, advance, invest, and use. Decisions are affected by such factors as consumer acceptance, patent laws, availability of risk capital, federal budget process, local and national regulations, media attention, tax incentives, and scientific discoveries.

Thus, knowledge and understanding of local, state, national, and global issues shows the interactions among science/technology/society and are essential to scientific literacy. Studying topics such as population growth, antibiotics, space exploration, water resources, world hunger and food resources, solar energy, war technology, crop improvement, land use, human health and disease, hazardous substances, extinction of plants and animals, nuclear reactors, mineral resources, communications, and transportation provides such knowledge and understandings. Understanding these issues will enable students to make intelligent decisions, to understand, and to cope with the world in which they live. (Far West Laboratory, 1989)

Goal 8: Laboratory Investigations/Hands-On Learning

> **To acquire skills for learning through concrete and manipulative use of instruments and materials of science.**

One of the key features of the scientific enterprise is the active investigation of natural phenomena. Scientists engage in active inquiry, investigation, and research to find out information, test ideas, and seek explanations. Teaching science should be consistent with the processes and procedures that characterize the nature of scientific inquiry. Students need many opportunities to learn science by doing science both in and outside the classroom. A wide variety of hands-on interactions should be included at all levels so students have repeated experiences with procedures of investigation, such as observations, measurement, and experimentation—along with extensive interaction with equipment and concrete materials. It is as important for the first grader to be able to manipulate a hand lens, a magnet or other materials through hands-on activities as it is for the high school student to be able to use chemistry equipment, microscopes, or other laboratory apparatus. Traditional scientific equipment, such as test tubes, balances, meter sticks, and microscopes have traditionally had a prominent role in effective science programs. Nontraditional equipment such as calculators,

computers, lasers, and videodiscs may also play a prominent role in effective science instruction in the future. Their use and contributions need to be evaluated so tomorrow's students will have the skills necessary to access the wealth of information that will be come available through technological advances. Given the key role that hands-on learning plays in the acquisition of scientific proficiency, equipment and materials must be made available to all students, elementary through secondary. Consideration needs to be given to provide adequate space, facilities, materials, and class sizes that facilitate concrete and manipulative experiences for students.

III. ACHIEVING SCIENTIFIC LITERACY: STUDENT OUTCOMES AND EXAMPLES OF INDICATORS

The eight goals delineated and defined in Section II are the key components that should be reflected in the K-12 science curricula in Arizona schools. Collectively, the achievement of these goals by students should lead to a more scientifically literate citizenry. In Section III, a framework for curriculum development has been constructed to provide school districts with a vision and structure for developing local science curricula that reflect the needs of their schools and communities. This framework is intended to be used by local districts as a starting point for discussion and reflection for the development of a cohesive K-12 science curriculum which encompasses all of the student outcomes.

Section III is organized into three subsections containing *Student Outcomes* and *Examples of Indicators* for: Primary (K-3), Middle Grades (4-8), and Secondary (9-12). The *Student Outcomes* define and clarify the intent and scope of each major goal area. The *Student Outcomes* are the mandated core competencies from which a district's K-12 science curiculum will be developed. The *Examples of Indicators* are that, only examples, of student behaviors and skills that show student achievement of the *Student Outcome*. The *Examples of Indicators* given are not mandated topics. School districts may use these indicators to simulate the development of district indicators that correspond with the prescribed student outcomes. Locally developed indicators illustrate that a student outcome has been achieved. Examples of indicators can be developed for all science disciplines in a variety of educational settings using different educational strategies.

K-3

Goal 1: Attitudes/Habits of Mind

To develop positive attitudes and excitement toward learning science and confidence in one's ability to do and understand science.

Student Outcomes	Examples of Indicators
Exhibits curiosity about the world	• willingness to ask questions • follows one's curiosity by seeking answers to one's questions about the natural world
Recognizes that questioning is a normal part of the process of science	
Exhibits openness to new ideas	• maintains an open mind by actively listening and by showing a willingness to discard positions when warranted by scientific evidence
Is honest and objective	• accepts results • reports data accurately
Exhibits a sense of security in the science classroom	• chooses to take risks in a trustful environment by trying new tasks and skills • complies with safety regulations in handling tools and equipment
Demonstrates a sense of purpose while doing science	• demonstrates a sense of purpose by setting goals for learning about science • demonstrates initiative by taking steps to achieve one's goals in the science classroom • sees oneself as a problem-solver when confronted with a dilemma by generating different problem-solving strategies and seeking multiple solutions
Participates willingly in doing science	• assesses one's own growth and progress in the science classroom • identifies positive feelings experienced in the classroom
Cooperates with other students to find answers and solve problems	• approaches problems with a spirit of collaboration with others by demonstrating the use of appropriate social skills • maintains positive relationships with other group members who are working on a cooperative task

Goal 2: Nature of Science and Technology

To develop an understanding about the nature of science and technology.

Student Outcomes	Examples of Indicators
Uses science methods and experiences to explain observations and solve problems	• can perform a simple experiment in an effort to answer a question
Examines ways scientists make observations and solve problems	• identifies ways science can be practiced by many kinds of people at different levels of complexity

Goal 3: Science Content

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Acquires an understanding of the organizing concepts:	
Organization—Recognizes and demonstrates that ideas and descriptions about natural phenomena can be organized in different ways	• identifies the order of planting a seed, sprouting, adult plant, flower and fruit • sorts objects (e.g., objects that sink, objects that float) • identifies groups of objects that have been designed by humans • recognizes the main components of earth are air, land and water • identifies the three basic components of soil as sand, silt and clay
Cause and Effect—Recognizes that cause-and-effect relationships exist in the natural world	• describes the differences of appearance in animals with the seasons • describes the motions of the sun, earth and moon and causes of day and night • observes the effects of heating or cooling water • explains the various forms of precipitation
Systems—Gives examples of the parts and interactions of natural systems	• explains the causes of various forms of precipitation • describes and illustrates the water cycle • constructs a simple technological device • identifies components in a habitat
Models—Creates or utilizes concrete models to understand/explain natural phenomena	• draws a simple food chain • constructs a model of a living system • identifies models that are bigger than, smaller than or the same size as the real object
Change—Recognizes that change occurs in the natural world	• recognizes sequence of growth states from baby to adult and seed to plant • identifies the seasons and describes them • measures and describes the growth of organisms • identifies types and rates of change
Structure and Function —Recognizes that there is a relationship between an organism's structure and its function	• collects information about animals by studying bones, teeth, body covering and other parts • relates types of bird beaks to what they eat • relates plant parts to the job they do • designs a device that has a particular function • describes a bicycle in terms of structure and function • explains why desert plants have spines

Goal 3: Science Content (continued)

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Diversity—Gives examples of similarities and differences evident in natural phenomena and organisms	• describes and illustrates day and night • classifies objects as living/nonliving, hard/soft, light/heavy or strong/weak • describes and illustrates night and day • observes and describes differences of students in class • identifies differences in pets • lists objects and organisms on the school grounds
Interactions—Recognizes there are interactions among the components of systems	• recognizes that plants and animals are different in different environments • investigates prehistoric animals and their habitats • investigates which substances dissolve in water • investigates prehistoric animals and their environments • explores the amount of energy required to move objects • identifies sources of engery that cause changes in matter

Goal 4: History of Science

To understand the historical contributions in science and the context in which they were made.

Student Outcomes	Examples of Indicators
Recognizes that science has changed over a long period of time	• examines differences in methods and equipment used by scientists in the past
Recognizes that scientific contributions have been made by people of different genders, racial and ethnic groups and from different countries	• identifies historical scientists and their contributions • examines technological developments of non-Western and native American civilizations; examples: Hohokam and canals, Aztecs and calendar, Papago and dryland crops

Goal 5: Thinking/Reasoning Skills of Science

To develop integrated thinking skills through science experiences.

Student Outcomes	Examples of Indicators
Develops and uses rational thinking skills	• describes and groups objects based on their color, shape, texture, size and as living or nonliving • identifies senses and describes how people use them • uses observations already made to predict future events • gathers data and keeps simple records • utilizes all appropriate senses in observing and describing events, properties and characteristics of objects • differentiates between actual observations and personal interpretations
Develops and uses creative thinking skills	• invents animals • adapts a plant to live in a jungle
Develops and uses critical thinking skills	• recognizes evidence that change has occurred • describes relationships among objects and events • utilizes measurement • answers questions by investigating • asks questions and tests them • makes inferences based on observations • sequences the stages of events according to their order of occurrence • constructs simple graphs, charts and tables

Goal 6: Personal Use of Science and Technology

To use experiences with science and technology in personal decision-making.

Student Outcomes	Examples of Indicators
Applies knowledge of science to make personal decisions	• lists ways science and technology can help people care for themselves
Applies knowledge and processes of science in situational problem-solving	• uses scientific principles to design an invention which reduces water use in the home • sets-up a recycling system at home

Goal 7: Societal Impact of Science and Technology

To increase understanding of the limits, possibilities and interrelationships among science, technology, society and the environment.

Student Outcomes	Examples of Indicators
Recognizes the relationship between science and technology	• recognizes that the invention of the telescope has led to a better understanding of the universe • recognizes that television is a result of combining many important scientific principles such as light, electricity, radio waves, etc.
Recognizes that science and technology can affect the way we live	• describes how the light bulb has changed the way people live and work • identifies ways and places that computers are used in our everyday lives • identifies ways that science and technology have improved the quality of life in Arizona's arid environment: canals, air conditioning, evaporative cooling.
Recognizes that science and technology can affect the environment	• relates air pollution to automobiles and industry • recognizes steps taken by industries, such as mining, that are beginning to restore previously damaged land

Goal 8: Laboratory Investigations/Hands-On Learning

To acquire skills for learning through concrete and manipulative use of instruments and materials of science.

Student Outcomes	Examples of Indicators
Uses simple scientific instruments and everyday materials to investigate the natural world	• observes and classifies attributes of rocks using a hand lens, balance and water • investigates the effect of color on heat absorption using water, cans, construction paper, thermometers and a timer • observes, collects and characterizes plant life in area of school, using paper towel and cardboard plant press • rears insects in classroom using ice cream cartons, jars, screening
Demonstrates safe and proper techniques for handling, manipulating and caring for science materials	• stores materials in appropriate places • cleans work area

MIDDLE GRADES (4-8)

Goal 1: Attitudes/Habits of Mind

To develop positive attitudes and excitement toward learning science and confidence in one's ability to do and understand science.

Student Outcomes	Examples of Indicators
Is curious about natural phenomena	• asks questions • seeks out information about questions • brings objects of interest to school
Is open minded	• retracts prior conclusions when evidence warrants it • considers alternative points of view • ponders events that conflict with existing perceptions • actively listens to others
Is skeptical	• seeks evidence for conclusions • questions claims in making consumer decisions • examines critically the results of one's own and other's work • puts ideas to test before accepting or rejecting them
Relies on data, facts and observations	• requests data before accepting an idea • distinguishes between supported and nonsupported conclusions
Respects logical reasoning	• extends methods used in science to other fields of experience
Is honest and objective	• reports data accurately • recognizes bias • designs experiments ethically
Recognizes that not all data/scientific findings are definitive or complete	• recognizes more evidence can change conclusions, decisions and points of view, etc.
Is willing to modify explanations	• changes points of view with new evidence
Approaches scientific experiences with self-confidence	• takes risks by trying new tasks and skills • approaches problems independently • identifies self as problem-solver • labels positive self attributes of self and others in doing science • confronts problems with persistence
Cooperates with other students to find answers and solve problems	• uses appropriate social skills in a group

MIDDLE GRADES

Goal 2: Nature of Science and Technology

To develop an understanding about the nature of science and technology.

Student Outcomes	Examples of Indicators
Explains phenomena using scientific concepts	• relates the length and speed of a swing to frequency function of a pendulum • recognizes characteristics of plants that show adaptations to their environment • makes a model that demonstrates reasons for seasonal changes • utilizes knowledge of wave frequency/pitch to adjust/purchase an equalizer
Recognizes that the scientific enterprise provides explanations that can be: — durable — changeable — sometimes incomplete — developed over time — cumulative	• identifies the century that Newton's Law of Gravitation was formulated and relates to current phenomena • gives examples of evidence for a heliocentric universe that have gathered at different times • compares conductivity of materials before and after the discovery of superconductors • prepares a time line showing when different subatomic particles were discovered • relates advances in technologies and research techniques to acceptance of the theory of plate tectonics • compares and contrasts causes of diseases, some are known, some are not • summarizes data about the planets and relates this data to time it was gathered
Understands that science is not dogmatic	• describes an example of a scientific theory that has self-corrected (i.e., Einstein's theory is incomplete; predator/prey relationship theory changed with examining new data; Piltdown hoax)
Identifies the inquiry processes that lead to scientific explanations	• relates how observations can lead to explanations (i.e., Newton watching rainbows and prisms) • gives examples of reasons for a phenomena • plans an experiment using inquiry processes to explain an observation/event (i.e., why is rain acidic and the stream is not) • lists questions that could have led to some discovery or invention
Understands that science is a human intellectual activity	• compares tools used by Indians to make astronomic observations to modern ones • gives examples of scientific contributions made by prehistoric people in Arizona (i.e., engineering canals, agricultural products like cotton) • identify things from different cultures we use in ours (i.e., curare form South America for anesthetics)

Goal 2: Nature of Science and Technology (continued)

To develop an understanding about the nature of science and technology.

Student Outcomes	Examples of Indicators
Understands that science is conducted in an ethical manner	• reports results of experiments accurately • makes conclusions based on accurate data • recognizes that bias can affect the results of an experiment • debates/relates examples of unethical scientific practices (i.e., what happens if a drug company reports results of side effects inaccurately)
Understands that technological solutions can: — be changed/modified — be limited by design constraints — have good/bad solutions — be limited by risk factors and trade-offs — be monitored by feedback systems — be limited/changed by economic considerations	• analyzes the reasons for using leaded gasoline, unleaded gasoline and oxygenated gasoline • compares surgical techniques during last two centuries • makes a time line showing developments in rocketry • relates changes in communications • compares bridges built at different time periods in terms of earthquake resistance • compares the benefits of DDT with the risks and effects on wildlife • gives examples of benefits and risks of nuclear energy • debates the benefits of genetic engineering • simulates a public hearing for a proposed dam to generate power • analyzes governmental regulations re: marketing a new drug

Goal 3: Science Content

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Organization—Recognizes and explains that ideas and descriptions about natural phenomena can be organized in different ways	• analyzes an ecosystem in terms of its populations and communities • describes organizational patterns of matter such as atoms to molecules, crystals, etc. • identifies organizational patterns in space, such as earth-solar system • identifies organization levels of technologies such as communication, agriculture, biotechnology, transportation, space and computer technology • describes component parts of natural and technological systems
Cause and Effect—Searches for and identifies valid cause and effect relationships in the natural world	• identifies the effects of poor nutrition on health • describes natural phenomena in terms of cause and effect (e.g., weather, erosion) • creates experiments that deal with the reactions of a variety of living things under different environmental conditions • discovers concepts of the physical world through experimenting with cause-and-effect relationships with physical phenomena • designs an invention to produce a desired effect
Systems—Defines and delineates the parts of natural systems	• defines the relationships of part of an ecosystem • applies the concept of system to different objects, events and organisms (i.e., weather systems, solar systems, star systems, hydrologic cycle, simple machines, aquarium) • describes the characteristics of different natural and technological systems (i.e., the boundaries, components, feedback, resources) • identifies technologies as systems or interrelated subsystems (i.e., furnace and thermostat, rockets) • consturctssystems that apply science concepts (i.e., electrical circuits, robots, simple machines, inventions)
Models—Represents phenomena in conceptual, mathematical and physical models	• creates conceptual, physical or math models to describe or explain science concepts or systems • states different scales of time, space and matter • constructs a graph of data that represents a model of what is happening in an experiment • describes the use of model in the workings of technology (i.e., testing boats and cars in tanks and wind tunnels) • constructs prototypes of space stations, moon colonies or space vehicles • constructs models of linear and exponential growth

Goal 3: Science Content (continued)

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Change—Identifies rate and patterns of change in the natural world and technologies	• identifies changes in an ecosystem • explains the behavior of matter as heat is added or removed • explains the change in pressure of a fluid in proportion to the depth • describes how different materials affect the rate of electric current • distinguishes the change of the position of the planets from the star • explains the reason for changes in the phase of the moon • explains the formation of metamorphic rocks • describes physical changes during human growth and development • relates examples of how changing earth conditions have caused changes in biotic communities • distinguishes changes in matter whether it be either physical or chemical changes • discusses how changes in the season occur • illustrates the continuous properties of color in a spectrum
Structure and Function—Draws relationships between the characteristics of parts of organisms or components of systems and the actions they perform	• designs a plant or animal to meet conditions of habitat • identifies adaptations of animals that enable survival in different environments • invents a simple device for measuring wind velocity • analyzes different wind configurations that affect the flight of planes • analyzes the structures of plants to determine their suitability to different biomes
Diversity—Recognizes the importance of diversity in the world	• relates the concept of change to simple chemical reactions • describes how biotic community changes can result from climatic changes • examines a variety of new substances formed through chemical reactions (iron rusting, sulfur burning, hydrolysis of water) • evaluates the effect of climate and environmental forces of different landscapes
Interactions—Understands that the interaction of matter and energy determines the nature of the environment	• describes the interaction of the earth, moon and sun in relation to the tides • relates the physical and chemical changes of substances to their special properties • explains weather changes to the interactions of masses of air at different temperatures and pressures

MIDDLE GRADES

Goal 4: History of Science

To understand the historical contributions in science and the context in which they were made.

Student Outcomes	Examples of Indicators
Understands that scientific contributions have been made by all kinds of people everywhere in the world	• identifies examples of women, minority, eastern and western people that have made significant contributions to science (.e., Curie, Carver, Lister, Pasteur, Edison, etc.) • gives examples of Arizonans that made major contributions (i.e., Lowell, Douglas, Merriam, Kitt)
Identifies major scientific milestones that have revolutionized thinking of the time	• describes contributions of Mendel, Rutherford, Lavoisier, Newton, Galileo, Darwin, etc.
Traces historical developments in science and technology to contemporary counterparts	• relates how simple experiments by Mendel have led to genetic engineering • makes a time line showing the development of atomic structure from Rutherford to quarks • analyzes advances in flight from Wright brothers to Space Shuttle • traces the development of modern immunology from Pasteur's method of vaccination of smallpox
Gives examples of how science and technological applications have changed over time	• compares and contrasts how the development of materials technology and products have changed over time; bronze to space age, plastics/ceramics
Understands that scientific and technological achievements build upon another	• relates the data gathered using early telescopes to data obtained from the Explorer or Galileo probes • gives examples of modern technologies that depend upon electricity

MIDDLE GRADES

Goal 5: Thinking/Reasoning Skills of Science

To develop integrated thinking skills through science experiences.

Student Outcomes	Examples of Indicators
Accurately describes natural phenomena	• describes objects in terms of observable characteristics • classifies objects in terms of observable characteristics • describes, classifies and measures objects in terms of variables such as length, area, weight, volume and density • identifies variable and constant characteristics of groups of objects • measures, records, graphs the frequency of occurrence of certain values of characteristics in a sample of objects
Uses imagination and creativity in solving problems	• combines objects and ideas in new ways • produces alternative or usual uses for objects • makes an invention to meet a personal need • designs devices and machines given certain material, designs a model bridge to withstand a particular weight • brainstorms a list of alternative solutions for local or school problem such as litter
Formulates questions about nature, that can be done by an investigation or an experiment	• recognizes an experimental question from observation of nature or the context of a paragraph or article • identifies questions and hypothetical solutions related to a local problem • distinguishes between an observation and an inference • distinguishes between descriptive and experimental questions
Recognizes, generates and states alternative hypotheses and theories	• recognizes the tentativeness of a hypothesis or theory
Distinguishes a hypothesis from a question	• generates systematically all possible combinations of hypotheses
Generates and states logical predictions	• differentiates between hypotheses and predictions
Plans and conducts controlled experiments to test hypotheses	• selects reasonable alternative hypotheses to test • differentiates between an uncontrolled observation and an experiment involving controls • recognizes that only one independent factor in an experiment should be variable • recognizes the independent variable and the dependent variable • recognizes experimental and technical problems inherent in experimental designs

Goal 5: Thinking/Reasoning Skills of Science (continued)

To develop integrated thinking skills through science experiences.

Student Outcomes	Examples of Indicators
Assesses components of experimental design	• identifies an experimental design that cannot yield an answer to the question • determines whether an experiment was designed to test the specific hypothesis stated • determines whether the method of collecting the data was unreliable • evaluates the accuracy of data • determines if data are insufficient in number • identifies experiments in which proper controls were not used
Collects, organizes and analyzes relevant data	• recognizes existence of errors in measurement • recognizes when the precision of measurement given is warranted by the nature of the question • constructs tables and graphs with the values of two variables on a single graph • sees that there can be discrepancies in data • recognizes prevailing tendencies and trends in data
Draws and applies reasonable conclusions	• evaluates relevancy of data and draws conclusions through a comparison of actual results with predicted results • recognizes data which are unrelated to the hypothesis • recognizes that some experiments are inclusive • recognizes the tentativeness inherent in all scientific conclusions • applies conclusions to new situations • refrains from applying conclusions to new situations which are not closely analogous to the experimental situation • evaluates the evidence for two kinds of energy generation and chooses the "best"
Employs decision-making skills in applying scientific knowledge and processes	• identifies the issue • generates alternative courses of action • assesses the consequences of actions • makes choices • evaluates choices
Assesses the possible effects and risk factors of implementing a new technology	• judges the benefits and liabilities of the supercollider • evaluates the impact of genetically engineered bacteria in the environment

MIDDLE GRADES

Goal 6: Personal Use of Science and Technology

To use experiences with science and technology in personal decision-making.

Student Outcomes	Examples of Indicators
Identifies instances of scientific concepts in everyday life experiences	• explains the underlying scientific principles that make common objects work • explains interactions in weather phenomena • explains the reasons for the aerodynamic design for transportation vehicles
Applies learned science concepts and skills to everyday technological problems	• improves the energy efficiency of home • develops ways to keep cool during warm days • develops a system to make biodegradable garbage decompose faster • designs a container to keep eggs from breaking if dropped • creates a house-plan that will utilize passive solar heating
Uses scientific processes in solving problems that occur in everyday life	• determines what clothes to wear based upon the weather forecast
Evaluates mass media reports of scientific developments	• evaluates national decisions to take steps to limit production of fluorocarbons • assesses the development made in genetic engineering
Makes decisions related to personal health, nutrition and lifestyle based on knowledge of scientific concepts	• prepares lunch with foods that are not subject to rapid bacterial growth • designs a healthy menu • evaluates diet in terms of sugar and fat content
Recognizes that scientific knowledge, thinking processes and skills are used in a great variety of careers	• describes an example of scientific reasoning done by a scientist • relates knowledge being studied to people in their work (i.e., farmers, mechanics, biologist, plumber, engineer, soil chemists) • observes and describes ways in which specific scientific processes and skills being learned are useful to people in their work (e.g., a mechanic trouble shooting a problem in a car)
Understands that science and technology can affect individual lifestyles	• describes how lifestyles have changed as the result of product development • recognizes that science knowledge makes it possible to make wise decisions about lifestyles • describes the specific knowledge of the human body that makes it useful in deciding about food and chemical substances

MIDDLE GRADES

Goal 7: Societal Impact of Science and Technology

To increase understanding of the limits, possibilities and interrelationships among science, technology, society and the environment.

Student Outcomes	Examples of Indicators
Understands that developments in science and technology affect the condition of life	• describes the impact of fertilizers and urban run-off upon rivers, estuaries and coastal waters • identifies the arguments of why some chemical pesticides have been discontinued
Understands that science and technology have been applied to solve human problems and enhance human creativity	• identifies major scientific or technological advances and how they affect the way people live • predicts how our lives and surroundings would be different if some particular advance had not been made • describes how an art form such as music, performing arts or sculpture has changed in response to advancing scientific knowledge and technological applications
Understands that humans exert an ecological dominance	• explains the reasons why deforestation of the planet is occurring and the impact upon species • researches cases of environmental pollution from chemical pesticides that have resulted in the discontinued use of that product • relates the effects of population growth in Arizona
Understands that society's response to scientific and technological developments affects the direction of research and development	• evaluates the expenditure of money in pursuing new technologies
Understands that science and technology influence economic growth which, in turn, affects the progress of science and technology	• relates examples of scientific developments that have resulted in economic benefits
Understands that the equilibrium in the biosphere is affected by human use	• analyzes current information on the ozone layer and possible effects • assesses the effects of continued use of fossil fuels • evaluates the impact of ocean dumping on marine life • evaluates the loss of stream site communities (riparian areas) in Arizona
Understands that the global or local impact of science and technology on ecological systems are complex and not always predictable	• cites the ramifications of use of DDT • describes the impact of Glen Canyon Dam on the ecosystems of the Grand Canyon

Goal 7: Societal Impact of Science and Technology (continued)

To increase understanding of the limits, possibilities and interrelationships among science, technology, society and the environment.

Student Outcomes	Examples of Indicators
Examines how man's imagination and society's needs influenced scientific and technological advancements	• gives an example of how the culture at the time relates to science/technology (i.e., prehistoric canals around Phoenix, more leisure time from labor-saving devices like microwave ovens) • gives examples of advancements that have been made because of economic impetus: plastics; agricultural hybrids; machinery; computer chips; communications satellites, etc. • explains the historical/political context for some significant advancements (i.e., radar, penicillin, spy satellites, space race, etc. • identifies societal needs that have caused advancements in science and technology (i.e., more food production, diseases, conflicts, transportation needs, communication needs, sanitation, population growth) • gives examples of key individuals who have made significant contributions to the advancement of science/technology: inventors, politicians, scientists

MIDDLE GRADES

Goal 8: Laboratory Investigations/Hands-On Learning

To acquire skills for learning through concrete and manipulative use of instruments and materials of science.

Student Outcomes	Examples of Indicators
Demonstrates the ability to use materials (laboratory, household, natural objects, etc.) to acquire science concepts	• manipulates tools of observation, measurement and investigation • selects appropriate tools for observations, measurement and investigation • designs tools and apparatus for investigations (homemade barometer, Cartesian divers, etc.) • records data in a form which reflects the accuracy of tools and instruments • uses mocrocomputer-based labs, computer interfaces for data collection and analysis
Demonstrates the proper techniques for handling, manipulating and caring for science materials	• practices established safety procedures • maintains appropriate life-supporting environments for plants and animals • cares for organisms in a respectable and legal manner • demonstrates proper techniques for cleaning, storage and disposal of science materials
Conducts explorations and investigations in a variety of nonclassroom settings	• conducts field studies in the natural environment • investigates science museums, arboretums, zoos, school yards and gardens • visits local industrial sites and factories

SECONDARY (9-12)

Goal 1: Attitudes/Habits of Mind

To develop positive attitudes and excitement toward learning science and confidence in one's ability to do and understand science.

Student Outcomes	Examples of Indicators
Is curious about natural phenomena	• asks questions • seeks out information
Is open minded	• retracts prior conclusions when warranted by evidence • listens to contrary views
Is skeptical of undemonstrated statements	• demonstrates willingness to question teachers • seeks evidence for scientific claims
Is objective (relies upon data gained in an orderly fashion)	• identifies bias • is willing to entertain opposite points of view
Works cooperatively with others	• participates productively in group projects • brings in ideas or materials to share • discusses ideas with other students • participates in class discussions
Approaches problems independently	• requires minimal supervision • suggests creative solutions
Approaches scientific activities with self-confidence	• volunteers for tasks • works with minimal supervision • acts as a peer leader
Perseveres when doing scientific activities	• completes tasks • copes with frustration

Goal 2: Nature of Science and Technology

To develop an understanding about the nature of science and technology.

Student Outcomes	Examples of Indicators
Exhibits a scientific world view	• recognizes types of phenomena that are measurable, verifiable and reproducible • considers the world to be understandable • discusses instances where scientific ideas are subject to change • recognizes that science has limitations • identifies so-called "scientific" statements that are overly authoritarian
Understands scientific inquiry	• demonstrates knowledge of the scientific method through laboratory experiences • can reason logically • is able to evaluate evidence • can identify and avoid bias
Understands that scientific enterprise is a complex social activity, and is organized into component disciplines	• identifies local scientific institutions • distinguishes between ethical and unethical scientific practices (i.e., original writing vs. plagiarism) • demonstrates knowledge of current events of science • illustrates that scientists participate in public affairs both as specialists and citizens
Understands that the technological enterprise provides solutions to meet human needs, but sometimes has unforeseen negative consequences, and is influenced by social and political climate	• is able to explain how world events might lead to technological advances • identifies benefits and problems associated with nuclear energy

SECONDARY

Goal 3: Science Content

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Students will develop a knowledge base organized around the following themes:	
Organization—Ideas and descriptions of the world can be grouped in different ways	Life Science • traces the level of organization going from a cell to a complete organism Physical Science • states how the periodic table can be used to predict chemical properties Earth and Space Science • differentiates between metamorphic, sedimentary and igneous rocks • relates rock types to Arizona phenomena such as Grand Canyon, Salt River Canyon, basin and range formation
Cause and Effect—There is constancy in cause-and-effect relationships which make change explainable	Life Science • explains the Law of Biogenesis • describes the serial stages in succession resulting in a climax community • explains how mitosis leads to species continuity • traces plant communities as they occur from desert floor to mountain top in Arizona Physical Science • gives an example of conservation of momentum • explains how the distribution of electrons in an atom effects chemical activity Earth and Space Science • predicts an area's climate when given some climatic variables for that area (e.g., effect of El Niño on Arizona's monsoon system) • explains why a person would weigh less on the moon than on the earth • describes the rock cycle • explains relationship between deforestation and decreased heat absorption in various regions; utilizee infrared satellite imagery of the earth to contrast temperatures between vegetated, nonvegetated and highly-vegetated areas.

Goal 3: Science Content (continued

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Systems—The natural world can be conceptually broken into subunits, which are relatively isolated from one another, but within which various components interact in complex ways	Life Science • identifies several systems within the human body and explains how they interact • constructs a simple taxonomic key Physical Science • identifies several systems, subsystems and their relationships in some common everyday equipment Earth and Space Science • identifies successive subsystems, beginning with galaxy clusters • describes the position of the Earth in relation to solar systems, galaxies and the universe
Models—Nature can be described in terms of qualitative, quantitative and theoretical representations	Life Science • draws a diagram of the cell membrane that shows how it can be permeable to a specific substance • constructs a model of an Arizona Barrel Cactus that expands and contracts with water storage Physical Science • uses springs and balls to demonstrate wave and particle properties of light Earth and Space Science • creates model of desert stream showing sedimentation, erosion and 50-, 100- and 500-year flood stages • demonstrates the different phases of the moon using a light and a ball

Goal 3: Science Content (continued

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Change—All aspects of the natural world constantly undergo change	Life Science • gives examples of mutations • lists positive and negative effects of mutations • explains how environmental changes impact species survival (i.e., light and dark peppered moth) Physical Science • traces the changing forms of energy in a system, such as when a rock falls • discusses thermodynamic influences during chemical reactions • cites examples of matter changing from one state to another • traces the forms of energy present when a flashlight is turned on Earth and Space Science • shows how certain weather changes are related to the earth's orbital changes • traces observable changes in the environment as evidenced by the geologic record • explains how sedimentary rocks form and how this process provides evidence for continental drift
Structure and Function—Properties of an organism or systems are determined by organizational features	Life Science • compares plant structures (i.e., spines and leaves, and explains their significance to desert plants) • explains how the different parts of a cell determine its biological role • identifies structural adaptations of desert mammals (i.e., large ears, smaller size and pale colors) Physical Science • demonstrates how the arrangement of subatomic particles determines different types of elements • diagrams how different arrangements of carbon atoms lead to formation of graphite and diamond Earth and Space Science • explains how topographic and geologic features determine the climate of desert regions

Goal 3: Science Content (continued

To acquire and apply appropriate scientific knowledge to interpret the natural world.

Student Outcomes	Examples of Indicators
Diversity—Natural phenomena display a wide variety of similarities and differences	Life Science • discusses similar and different organs in two different organisms • explains the basis for taxonomy systems • compares diverse roles of organisms in food webs • explains how adaptation of environmental needs leads to a variety of organisms Physical Science • demonstrates that light has properties of waves and properties of particles • contrasts different forms of energy • describes how combinations of atoms lead to varieties of matter • lists several chemical and physical properties observable in matter Earth and Space Science • compares and contrasts land forms according to rock type, structure and properties and discusses mechanisms of formation • relates climatic conditions to geological formations • lists similarities and differences among planets in the solar system
Interaction—The interactions of matter and energy determine the nature of the environment	Life Science • constructs a food chain of organisms in a community • describes several examples of symbiotic relationships • explains how the circulatory system is dependent on the respiratory system Physical Science • gives examples of slow oxidation • explains how the number of electrons affect chemical composition • discusses what happens to matter in a nuclear explosion Earth and Space Science • discusses evidence for and against the various theories for moving continental plates • explains the relationship between the moon and tides • describes the consequences on earth resulting from sunspots and solar flares

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Goal 4: History of Science

To understand the historical contributions in science and the context in which they were made.

Student Outcomes	Examples of Indicators
Understands that technological demands, competition, controversy, world events, personalities and societal issues are all factors that relate to scientific discoveries	• discusses specific scientific discoveries that were stimulated by World War II; in Arizona the study of Guayule as a rubber substitute • explains contributions of key people such as Darwin, Crick, Mendel, Marie Curie, Einstein, etc. • describes possible changes in human life style that genetic engineering might bring about • discusses effects on the quality of life that biomedical engineering and surgical advances have caused
Understands the patterns by which major scientific ideas change	• explains some outcomes resulting from the Apollo program (i.e., demands for life support systems, lighter weight fuel and orbital predictions) • traces discoveries that have led and continue to lead to the conclusion that life is more complex than was previously believed • identifies contradiction generated by the phlogiston theory • identifies anomalies that led to a specified paradigm shift (i.e., the Earth is not flat, it is round)
Relates historical scientific knowledge to modern thought and life	• explains how the formulation of the cell theory affected beliefs about the causes of infectious diseases • describes how knowledge of genetics has led to improvements in agriculture and food supplies • relates how knowledge of atomic theory has given rise to the nuclear age • discusses the implications of viewing our planet as "spaceship earth"

SECONDARY

Goal 5: Thinking/Reasoning Skills of Science

To develop integrated thinking skills through science experiences.

Student Outcomes	Examples of Indicators
Develops the following thinking skills:	
Rational Thinking—Uses accepted knowledge to identify and solve scientific problems	• predicts interactions in a biotic community based on knowledge of food webs • observes and describes changes in populations in ecosystems over time • describes the common properties of the chemical elements in a specific group on the periodic table • measures length, volume, mass and density of objects commonly found in the laboratory • explains why scientific conclusions are never absolute
Critical Thinking—Is able to reorganize knowledge and apply it to new situations and subjects other than science	• classifies organisms into groups according to common characteristics • collects and analyzes data on objects rolling down an inclined plane • calculates the change in volume of a gas resulting from a change in temperature or pressure • infers relationships among pressure, temperature and volume of a gas form specific measurements • draws generalizations about the locations of earthquakes • interprets the fossil record from various points of view • applies steps of the scientific method to a variety of problems
Creative Thinking—Is able to generate new knowledge from past experiences	• designs an experiment to show how a certain trait is inherited • makes an inference from given temperature changes resulting from specific amounts of heat to a system • designs, performs and evaluates an experiment for studying the effects of acid rain • shows imagination and divergent thinking in creating unique solutions to problems • predicts ways that technology will help solve the world food shortage problem

SECONDARY

Goal 6: Personal Use of Science and Technology

To use experiences with science and technology in personal decision-making.

Student Outcomes	Examples of Indicators
Demonstrates knowledge of available careers in science and technology	• describes various careers associated with science (i.e., research scientist, lab technician, physician, hydrologist and astronaut) • writes job descriptions for various science careers
Recognizes science as a key component of many other careers	• cites examples of nonscience careers that utilize science and technologies • explains how science is an integral part of other careers, such as beautician, landscape architect and law enforcement officer
Recognizes that scientists perform many of the same activities that are performed in the science classroom	• using an actual scientific investigation which was performed, identifies the phenomena studied and how the eventual conclusions were reached
Utilizes scientific knowledge to guide personal decision-making	• selects products that will have the least impact on the environment

SECONDARY

Goal 7: Societal Impact of Science and Technology

To increase understanding of the limits, possibilities and interrelationships among science, technology, society and the environment.

Student Outcomes	Examples of Indicators
Understands the interrelated nature of science, technology and society	• evaluates the impact of societal values on animal research • explains why current laws inhibit research on fetal tissue • traces the changes in lifestyles over the past 30 years due to the development of computers • identifies products used in everyday life which originated from the space program (i.e., teflon and velcro) • explains the value of water-conserving devices (tiolets, drip irrigation, gray water recycling), use of drought-resistant plants and current legislation on Arizona's well-being
Is aware of and /or understands the scientific aspects of current issues	• cites examples of human impact upon the earth's ecosystem • describes potential applications of genetic engineering • identifies the pros and cons of the ability of parents to select the sex of offspring • designs a space station that supports human life • discusses nuclear wastes and their disposal • identifies potential global effects resulting from depletion of the ozone layer • explains the chemical reactions resulting from acid rain • predicts how the world will change if cold fusion becomes a reality • explains the importance of Arizona's native plant protection laws • explains results of recent space probes • discusses how the rising level of CO_2 causes the greenhouse effect • evaluates the effects of exploration for and the use of petroleum on ecosystems

Goal 8: Laboratory Investigations/Hands-On Learning

To acquire skills for learning through concrete and manipulative use of instruments and materials of science.

Student Outcomes	Examples of Indicators
Demonstrates the ability to use materials (laboratory, household, natural objects, etc.) to acquire science concepts	• manipulates tools of observation, measurement and investigation • selects appropriate tools for observations, measurements and investigations • designs tools and apparatus for investigations (homemade barometer, Cartesian divers, etc.) • records data in a form which reflects the accuracy of tools and instruments • uses computer interfaces for data collection and analysis
Demonstrates the proper techniques for handling, manipulating and caring for science materials	• practices established safety procedures • maintains appropriate life-supporting environments for plants and animals • cares for organisms in a respectable and legal manner • demonstrates proper techniques for cleaning, storage and disposal of science materials
Conducts explorations and investigations in a variety of nonclassroom settings	• conducts field studies in the natural environment • investigates science museums, arboretums, zoos, school yards and gardens • visits local industrial sites and factories

IV. IMPLEMENTING THE SCIENCE ESSENTIAL SKILLS

Intent and Implications

Sections II and III describe an expanded view of science and technology education and emphasize **what** students should learn. The committee also recognizes that **how** science and technology is taught is just as important. Section IV describes the **characteristics of a curriculum** designed using this framework and discusses some of the instructional implications that are in the goals and *Student Outcomes*. Section IV is intended to provide districts with background information, guidance, and clarification during their curriculum development process.

Section IV will assist districts in the design of local curricula, determining appropriate instructional strategies, and establishing the necessary support structures for teachers for implementation. The committee urges local districts to provide adequate time and resources to revise or restructure science programs and to train teachers to use appropriate materials and supplies.

Characteristics of Science Curricula Developed From The Framework

Establish a K-12 Continuum With Balance and Articulation

The 1986 National Assessment of Educational Progress (NAEP) for science reports that the trends across five national assessments from 1969 to 1986 show patterns of initial declines followed by some recovery at all age groups assessed. In general, the gains made in the last few years have not equaled the declines of previous years. (Mullis, 1988) International comparisons also reveal that American students are lagging behind those of other countries in science achievement (Lapointe, 1989). Cross-cultural studies show major differences in science education between the United States and other countries. The science curricula and instructional approaches in other countries incorporates more interdisciplinary topics in each year with effort made to maintain continuity across the grades. By contrast, most American schools have students study one science discipline a year, and then move to another discipline the next year—commonly referred to as the "layer-cake curriculum." (Lapointe, 1989)

The science curricula developed by districts should strive to ensure that there is continuity from year to year and that the overall K-12 curriculum introduces,

reinforces, expands, and enriches the eight goals and *Student Outcomes* contained in the essential skills curriculum framework. Efforts should be made during the curriculum construction process to link student learning from year to year. Attention also needs to be given to not separate the overall curriculum into distinct segments such as Primary, Middle Grades and Secondary that are independent from each other. This will necessitate that all levels of a district cooperate with one another and for elementary districts to collaborate with the high school districts to avoid stratified learning.

The most effective science curriculum will be one in which learning experiences are provided with appropriate emphasis on all the eight goals identified throughout the student's school career K-12. These eight goals clearly define what is meant by scientific literacy. Traditionally, science curricula have over-emphasized the knowledge component at the expense of the other components. This common tendency has resulted from a similar over-emphasis of the knowledge component in science textbooks and in the content of science courses organized by specific science disciplines.

Districts are urged to identify and include in their curricula scientific principles and processes that can have utility for the student for personal decisions, that promote social responsibility, and enriching experiences that enhance childhood. In addition to these considerations, the content chosen by districts needs careful attention so ideas and topics are chosen because they have basic, lasting scientific value.

The K-12 science curricula requires articulation both horizontally and vertically. Horizontal articulation means that the eight goals will be represented at all grade levels. There are many opportunities to include appropriate activities for students of all ages that will contribute to the achievement of all eight goals by the end of the child's school career. Vertical articulation means that concepts, skills, and attitudes encompassed by the eight goals of this framework need to be introduced and reinforced along a continuum K-12. Each grade requires appropriate science experiences and expectations consistent with the cognitive and physical abilities of the students. It is the responsibility of the district to determine the topics, skills, and specific learning activities that will be taught in each grade. This local autonomy should provide districts with the flexibility necessary to design science programs that address local needs, resources, and students.

Science for All Students

Science curricula should be designed to meet the needs of students regardless of sex, ethnic origin, or economic status. Current demographic trends indicate that many school systems will have "minority majorities" in the near future. The populations of minority and at-risk youth, and the numbers of dropouts and graduates without solid backgrounds in science and technology are increasing. In a technologically advanced culture, the scientifically illiterate are disenfranchised in educational, economic and political arenas. Driven by concerns of domestic equity and international economic competitiveness, science educators must help ensure that all students be provided equal opportunity to succeed in science-related endeavors. School districts need to consider these demographic trends while developing or revising their science programs.

Science curricula developed around the Arizona Science Essential Skills will assure that all students will be scientifically and technologically literate after completing their required science courses. All science offerings can and should emphasize utility and application for all students, and not be diluted versions of college-bound courses.

Lifelong Learning

Most science has been taught for the student who will eventually go to college or choose a career associated with science or technology. The primary goal in Arizona for the future is greater scientific literacy for all students. The basic concepts, skills, and attitudes proposed in this framework will enhance the life long learning abilities of all students, including those few who will eventually become professionals in science and technology.

It is anticipated that not only will all students need greater proficiency with science and technology to keep pace with a rapidly changing world, but also, that "learning-to-learn" skills will be essential to one's ability to change careers and make personal, societal, and political decisions. The design of science curriculum should incorporate experiences and activities that will contribute to the ability of students to build self-confidence in their applying "learning-to learn" skills in both the formal (school) setting and informal (family and community) settings.

Conceptual Themes/Organizing Concepts

During the process of developing this curriculum framework, the committee recognized a need for students to prepare for the information age and to have an understanding of basic science concepts. The expansion of science and technology information and applications contributes to the world changing at an accelerating pace. There are some fundamental, enduring concepts that persist over time and contribute to explanations for how our world works. In reviewing many structures for this curriculum framework, the organizing concepts structure was chosen because it provides inclusion of those enduring ideas and also allows for changes to be incorporated into the curricula as they occur.

The specific concepts were included and are valuable for several reasons:

- They are applicable to both science and technology.
- They accommodate different developmental levels.
- They apply to the personal lives of children.
- They are powerful explanatory concepts.
- They reinforce the importance of understanding ideas in science, rather than just facts.

(Bybee, et al. 1989)

These organizing concepts should be viewed as the "big ideas" of science and technology. They link the theoretical structures of the various scientific disciplines, and show how they are logically parallel and cohesive. Scientific literacy lies not only in knowing facts and theories, but in understanding the connections that make such information manageable and useful.

Science can be organized and taught in many different ways. The conceptual arrangement of this framework is designed to encompass and connect a great deal of the basic data, evidence, and theories of science. The intent is the improvement on recitation of disunited science facts and examples that has come to pass for science in many current curricula and instructional materials. Educators and curriculum developers are encouraged to utilize these organizing concepts as the vehicles for articulation throughout the K-12 science programs in their schools.

Making these organizing concepts a major emphasis in science curricula reflects what scientists really do, and what science really is. Unifying constructs

are a part of any philosophically united discipline. In science, the concept of organization can be found when learning about plants, ecology, chemistry, or physics. Additionally, scientists do not merely collect facts and categorize them. Facts are useful only when they are connected to the larger questions of how the natural world is, how it works, and how it all fits together.

Clearly, science and technology are expanding so rapidly that some kind of conceptual organization for students to use in learning science is more than just helpful; it is essential. If the basic concepts of one field can be transferred by connection or analogy to another field, the student will feel that there is a purpose and logic to the systems. If curricula and instructors are successful in developing concepts for students to use in connecting and integrating science facts and theories, then this intellectual habit will carry over and enrich other fields and disciplines. These conceptual themes are NOT visualized as the titles of textbook chapters, units or instructional programs. They are suggested as a means of linking facts and ideas within and among scientific disciplines. The purpose of using these organizing concepts in science curricula would be defeated if focus of science education now shifted to constant iteration of these isolated terms. Rather, these concepts should be integrated into existing or revised curricula to make it more unified and more logically developed for students.

Integration

The vision for reform in science education is also reflected by the other state documents for Essential Skills in Language Arts, Social Studies, Mathematics, Art and Health that call for changes/reforms in those curricular areas. Examination of all these documents reveals certain common themes and goals—especially the promotion and development of thinking and reasoning. Given the time constraints and heavy demands placed upon teachers to comply with all these mandates, it will be necessary to be cognizant of these other essential skills while developing new or revised science programs. It is recommended that time devoted to science and technology be complemented by incorporating reading, writing, and mathematics into the science and technology programs; and conversely, science and technology can be integrated with other subjects. Just as using common organizing concepts can add relevance and logic to science curricula, finding appropriate conceptual connections among other subjects and science can assist in not only meeting stated goals, but also give added relevance and meaning to the total education of the child.

Less is More—Depth as Opposed to Breadth

In general, this curriculum framework calls for students to study fewer concepts in greater depth, i.e., concentrating on several major organizing concepts, rather than on specific scientific or technological facts. A conceptual orientation to science curricula can require that some material currently found in existing programs be shortened or eliminated. In evaluating what should be included, topics, facts, and theories should be selected because they support and develop the basic ideas of a field and the concepts that connect these ideas. Current science textbooks are plagued by what Harriet Tyson-Bernstein call "the Mentioning problem" This is what happens when an instructional program tries to include too many terms and concepts. They end up being "mentioned" instead of explained. (Tyson-Bernstein, 1988). Because developing new or more sophisticated concepts takes time, students should pursue a topic or phenomena in depth. There should be a decreased emphasis on facts and definitions, with an increased emphasis on quality, understanding, and applying thinking processes. Use of the Arizona Science Essential Skills provides guidelines in evaluating and choosing instructional materials that focus on and reinforce the organizing concepts.

Multiple Resources

This framework emphasizes the connections of science with personal choices and science related topics, issues, and problems. These considerations require the use of multiple resources including textbooks, library books, newspapers, reference materials, news and science magazines, and supplemental materials. It will be necessary to use multiple resources including informal science education institutions to provide the broad range of activities and expetiences necessary to meet the student outcomes in this document.

Characteristics of Instruction

Pedagogy refers to instructional methods that are used to teach. The curriculum characteristics presented have some instructional implications attached. A new or revised science curriculum which follows these guidelines will need teachers who have or need to acquire skills to teach science. Efforts need to be made to move from transmissive teaching to more active approaches and varied approaches. Schools will need to assess skills of teachers to determine staff development needs. Many teachers in practice today do not have the preservice

preparation necessary to teach science and technology following these new guidelines. Collaborative efforts among schools and the state will become imperative to bridge the gap between existing practices and the practices recommended.

There are some special pedagogical considerations for science and technology instruction that should guide schools in designing and implementing science curricula. A major emphasis in science and technology pedagogy is that methods and strategies chosen should reflect the nature and spirit of the scientific enterprise.

Teach Consistent With The Nature of Scientific Inquiry

The goals of the Arizona Science Essential Skills define the attributes of students who will pass through our educational system. It is envisioned that these students will acquire an understanding of science and technology as ways of thinking and doing as well as bodies of knowledge. To accomplish this, students will need to be exposed to the kinds of thoughts and actions that are encountered in those fields. The recommended instructional strategies can contribute greatly to achieving effective science teaching.

Start With Questions

Using science and technology as the model, science instruction should begin with questions and events or phenomena that are interesting and familiar. Time needs to be given for students to get acquainted with things—including equipment, organisms, tools, and natural phenomena—to observe, describe, interact, be puzzled, ask questions, and then try to find answers.

Engage Students Actively

Students need repeated and varied experiences to learn science by doing science. Active learning experiences offer more opportunities for students with different learning styles, cognitive abilities, and language development to be

successful. Teachers should seek to expand their skills in selecting and implementing activities and investigations that promote active learning.

Use a Team Approach

Science and technology are often collaborative efforts, it is rare for individuals to be carrying out investigations or technologic applications in isolation. This collaborative nature of the scientific enterprise should be taught and reinforced by frequent group activity in the classroom. There are many effective cooperative strategies that can give students shared responsibility for learning with each other just as many scientists and technologists work collaboratively to achieve desired outcomes. Appropriate use of cooperative learning strategies can enhance student achievement, motivation, positive attitudes, and social interactions.

There are many successful cooperative models to draw from that are particularly suited to science and technology instruction. Strategies should be selected that exploit the full potential of cooperative learning and distinguish it from traditional small-group structures. Tasks should be structured so the spirit of positive interdependence develops, there is active face-to-face interaction among team members, individual accountability for mastering the material, group members are helped to develop interpersonal and small group skills, and feedback is given for both group functioning and academic tasks.

Do Not Separate Knowing From Finding Out

Science and technology are dualistic by nature. The scientific enterprise includes the body of knowledge that has accumulated and the processes and procedures that lead to that information. Science instruction should strive to keep that dualistic nature intact. Science teaching that tries only to impart accumulated information only leads to partial understanding of the utility of that information or how it was gained. Conversely, attempting to teach the processes and procedures of science in isolation, for example, one activity per year on the "scientific method" falls short of providing students with a reason for using these processes. To develop greater rigor in science education, students need to have many experiences "finding things out" for themselves.

De-emphasize the Memorization of Technical Vocabulary

"Understanding rather than vocabulary should be the main purpose of science teaching." (2061, p. 149) Teachers should be encouraged to introduce technical terms when they are necessary to clarify thinking and communication. Students should gradually build a functional scientific vocabulary that survives beyond the next test. "For teachers to concentrate on vocabulary, however, is to detract from science as a process, to put learning for understanding in jeopardy, and to risk being misled about what students have learned." (2061, p. 149)

Use Multiple Resources

Textbooks can be a useful resource for science instruction, but not the only resource. Just as scientists utilize previous knowledge and information, students

can benefit from reading, both in texts and other sources. However, students not only need frequent opportunities to read, but also to discuss new works and ideas with peers, and to relate that information to what they currently know. Students can profit from readings more after they have initially explored a topic in some concrete, active manner.

Given the changes in curriculum design and scope, existing textbooks will not suffice as the sole resource for teachers to accomplish implementation. It will be necessary to use **multiple resources**, including supplemental materials, audio-visual aids, informal science education institutions, and computers. Using multiple resources in conjunction with varied teaching strategies gives teachers the options needed to accomplish the goals of the Arizona Science Essential Skills.

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